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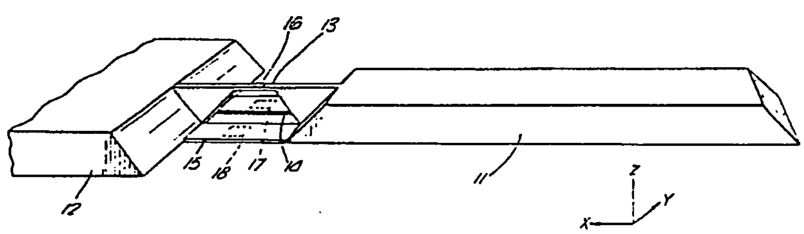
# (54) Accelerometer

(57) An accelerometer includes a beam member (11) displaceable in a first plane in response to an accelerating force. The beam is coupled to a support (12) via three flexible members (13, 14, 15) not all coplanar and provided each with a strain gauge (16, 17, 18). Deflection of the beam in the X, Y or Z directions provides a corresponding combination of outputs from the strain gauges.

*Fig.1.*




Reprinted front page

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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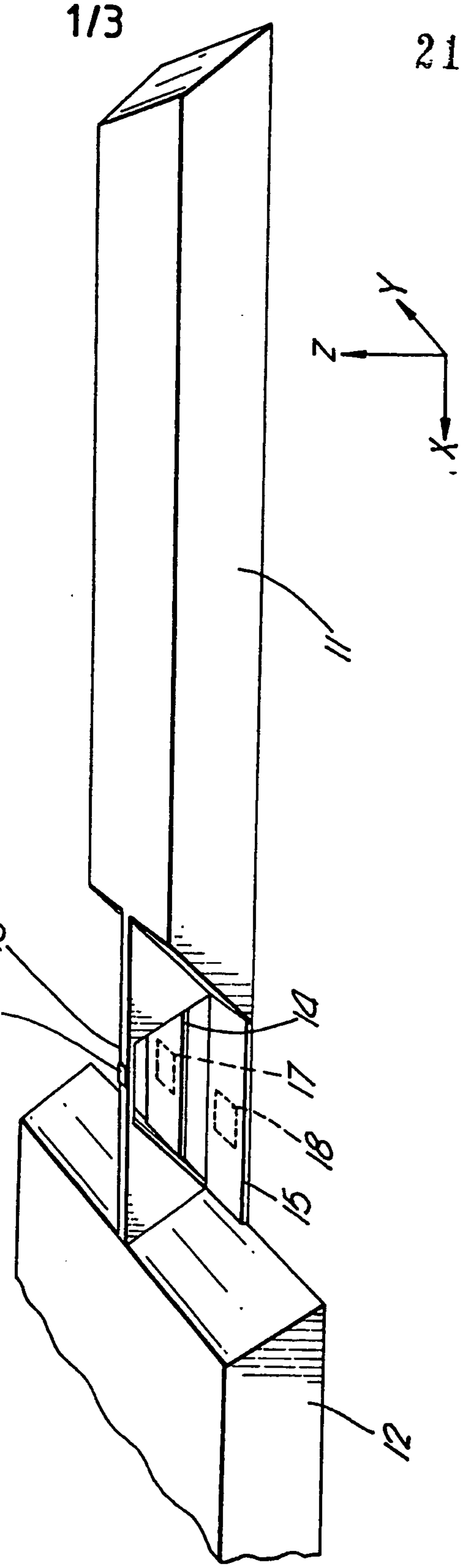


Fig.1.

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Fig. 2.

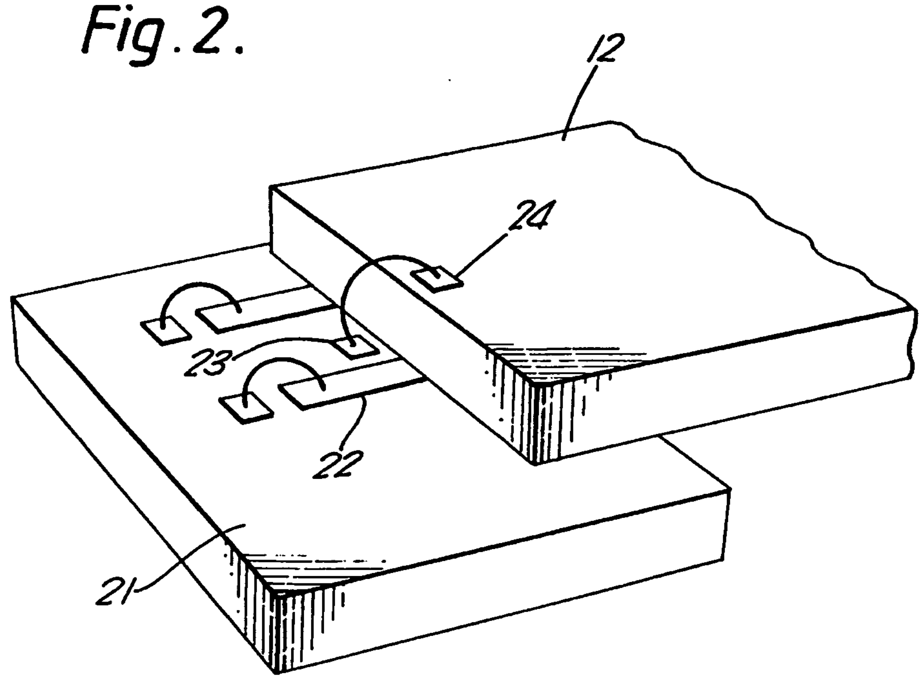
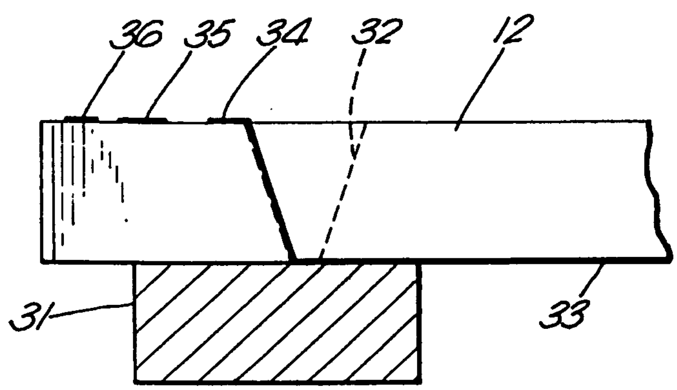



Fig. 3.



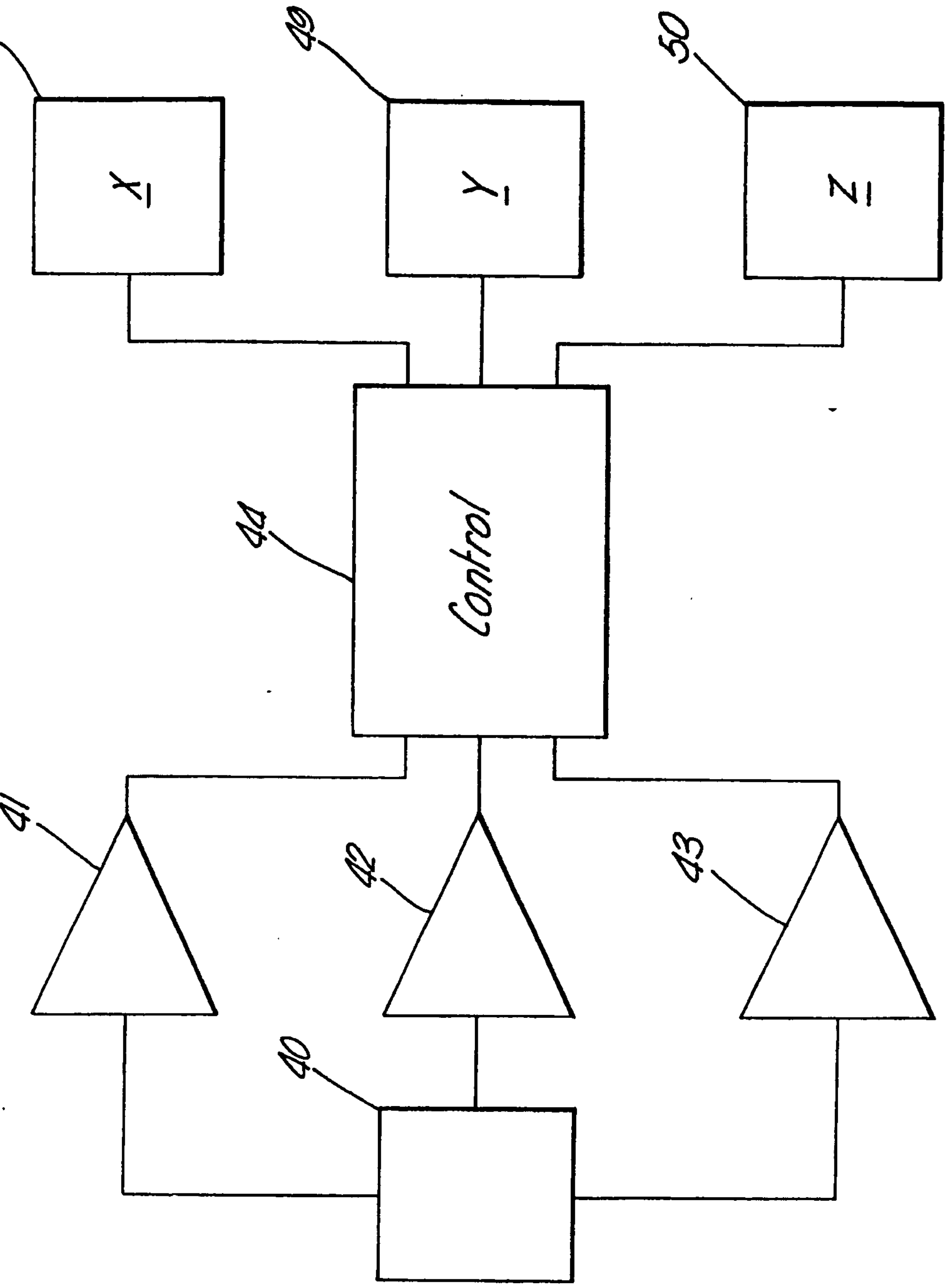



Fig. 4.

SPECIFICATION

**Accelerometer**

This invention relates to transducers, and in particular to inertial devices for detecting and measuring acceleration and to inertial guidance systems employing such devices.

Accelerometer transducers, e.g. of selectively etched silicon, conventionally incorporate a flexible elastic body one surface of which is provided with a strain gauge. Deflection or bending of the elastic body in response to an acceleration of the device produces a corresponding output from the strain gauge. These structures have inherent limitations. In particular they are unidirectional, i.e. the devices respond primarily to acceleration in one direction, and to measure accelerations in two or three dimensions further devices are required.

The object of the present invention is to minimise or to overcome this disadvantage.

According to the invention there is provided an accelerometer transducer for sensing accelerating motion in three mutually perpendicular directions, the transducer including a rigid beam member coupled to a support via three flexible members, not all coplanar, disposed at one end of the beam, and strain gauges are associated with each flexible member, the arrangement being such that deflection of the beam in response to an accelerating force causes a combination of tensions or compressions in the flexible members, said tensions or compressions corresponding to the direction and magnitude of the accelerating force.

Embodiments of the invention will now be described with reference to the accompanying drawings in which:-

*Figure 1* is a view of an accelerometer device responsive to accelerations in three mutually perpendicular directions;

*Figures 2* and *3* illustrate methods of providing electrical coupling to the device of Figure 1, and

*Figure 4* is a schematic diagram of an inertial guidance system employing the accelerometer of Figure 1.

Referring to Figure 1 the accelerometer transducer comprises a rigid beam member 11 coupled to a support 12 via three flexible members 13, 14 and 15. The flexible members are not all coplanar and, typically, are disposed such that one member 13 is contiguous with the upper surface of the beam 11 whilst the other two members 14, 15 are contiguous with the lower surface of the beam. Tension or compression of the flexible members 13, 14 and 15 is detected and measured via corresponding strain gauges 16, 17, 18, and disposed on each flexible member. Typically each strain gauge comprises an array of piezoresistors arranged in a Wheatstone bridge network.

The transducer of Figure 1 is responsive to accelerating forces in three mutually perpendicular directions. For example, we can take the X direction along the longitudinal axis of the beam 11, the Y direction transverse to the beam and the Z direction perpendicular to the plane of the beam. Deflection of the beam in the Z direction produces tension (compression) in the flexible member 13 and compression (tension) in the members 14 and 15. Deflection in the X direction causes tension (compression) in all three flexible members, whilst deflection in the Y direction causes tension (compression) of the member 14 and compression (tension) of the member 15. By measurement of the strain gauge output the magnitude and direction of the accelerating force can be determined from the magnitude and particular combination of these outputs.

The transducer of Figure 1 may be formed as an integral structure by selective etching of doped single crystal silicon. In this process the device configuration is defined by boron doping or by the use of an electrolytic etch strip. Typically those parts of the silicon crystal that are to remain unetched are doped with boron to a level of about $4 \times 10^{19}$ atoms per cc. The silicon is then masked and exposed to a selective etch comprising a mixture of catechol, ethylene diamine and water, or of potassium hydroxide and isopropyl alcohol. Such techniques are more fully described in our published specification No. 1,211,496 (J.C. Greenwood 6). The strain gauges may be formed as doped regions in the silicon and provided with electrical connections via metallisation tracks.

Figures 2 and 3 illustrate techniques of providing electrical connection to the strain gauges of the transducer of Figure 1. All these techniques overcome the problem of providing connection to the top and bottom surfaces of the transducer.

In the arrangement of Figure 2 the support 12 of the transducer is mounted on an insulating carrier 21. Solder tracks 22, e.g. located in corresponding grooves, are provided on the carrier surface and connect to the strain gauges 17 and 18 (Figure 1) via metallisation tracks (not shown) on the lower surface of the transducer. A further contact 23 is provided on the carrier 21 from coupling to a contact pad 24 on the upper surface of the transducer, which contact pad is associated with the strain gauge 16 (Figure 1).

Figure 3 is a sectional view of an arrangement whereby connection to all three strain gauges is provided on one surface of the transducer. The transducer support 12 is mounted on an insulating carrier 31 and is provided with an etched opening 32 between its upper and lower surface. A metallisation track 33 passes through the opening to provide connection from a contact pad 34 to the strain gauge 16. Contact pads 35 and 36 provide connection to the strain gauges 17 and 18 via corresponding metallisation tracks (not shown) on the upper surface of the transducer.

Figure 4 shows a schematic diagram of an inertial guidance system, e.g. for use in a vehicle. The system employs an accelerometer transducer 40 of the type shown in Figure 1. Accelerations in the X, Y and Z directions are sensed from the outputs of the three strain gauges which outputs are fed via corresponding amplifiers 41, 42 and 43 to a central control unit 44. The control unit decodes the combination of inputs to provide a measure of the ac-

celeration in the X, Y and Z directions. In response to the input signals received from the amplifiers, and to preset course information stored in the central unit, the unit provides output signals to X, Y and Z guidance controls (48-50) whereby the desired course may be maintained.

## CLAIMS

1. An accelerometer transducer for sensing accelerating motion in three mutually perpendicular directions, the transducer including a rigid beam member, coupled to a support via three flexible members, not all coplanar, disposed at one end of the beam, and strain gauges are associated with each flexible member, the arrangement being such that deflection of the beam in response to an accelerating force causes a combination of tensions or compressions in the flexible members, said tensions or compressions corresponding to the direction and magnitude of the accelerating force.
2. An accelerometer transducer as claimed in claim 1, and comprising a unitary body formed by selective etching from single crystal silicon.
3. An accelerometer transducer as claimed in claim 2, and including means for providing electrical connection of the strain gauges to a common surface region of the transducer.
4. An acceleration transducer as claimed in claim 3, wherein said means includes a through contact between two major surfaces of the transducer.
5. An accelerometer transducer substantially as described herein with reference to Figures 1 and 2 or Figures 1 and 3 of the accompanying drawings.
6. An inertial guidance system incorporating an accelerometer as claimed in any one of claims 1 to 5.

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